SLIDING MEMBER

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority based on Japanese Patent Application No. 2003-069262, filed March 14, 2003, the entirety of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to a sliding member provided with sliding layers.

[0003] Examples of a sliding member provided with sliding layers include, for example, a swash plate etc. of a swash plate type piston pump (variable displacement pump, compressor, etc.). The swash plate type piston pump is constructed so that a gas in a cylinder is compressed by a piston reciprocating in the cylinder following a rotating swash plate. In the pump of this type, the swash plate slides with respect to a shoe, which is a mating member interposed between the swash plate and the piston. The swash plate of the swash plate type piston pump rotates at a high speed and also receives a high pressure from the shoe.

[0004] Conventionally, as the above-described sliding member used for a swash plate type compressor and the like equipment, a sliding member in which coating layers consisting of a solid lubricant using polyamide-imide (hereinafter abbreviated to "PAI"), polyimide (hereinafter abbreviated to "PI"), or epoxy (hereinafter abbreviated to "EP") as a binder are formed on both surfaces of a base material has been proposed in JP-A-4-83914, JP-A-9-79262, JP-A-8-59991, etc.

[0005] On the other hand, in the above-described sliding member, a lubricating oil is supplied onto the sliding surface, and in particular, in the above-described swash plate type compressor or the like, a mixture of a refrigerant and a refrigerating machine oil, which is a lubricating oil, (refrigerant/refrigerating machine oil mixture) is supplied. Thus, the lubricating oil is supplied onto the sliding surface of sliding member. In a case where the equipment is not used for a long period of time, for example, as in the case of the compressor for an air conditioner, the refrigerant/refrigerating machine oil mixture becomes absent on the sliding surface of sliding member, and hence the sliding surface becomes in a dry state. If the compressor is started in this state, since some period of time is required before the refrigerant/refrigerating machine oil mixture is supplied onto the sliding surface, the sliding member slides in the dry state until the refrigerant/refrigerating machine oil mixture is supplied, so that a high load due to heat generation is applied to the part of the sliding layer of the sliding member, and thus the sliding member may seize. Therefore, there has been demanded a sliding member which can slide for a long period of time without seizing even in the dry state before the refrigerant/refrigerating machine oil mixture is supplied sufficiently.

[0006] In the case where the sliding layers consisting of a solid lubricant using a thermosetting resin such as PAI, PI, or EP as a binder are formed on both surfaces of the base material as described above, since the thermosetting resin forming the sliding layer has a low thermal conductivity, there arises a problem in that heat generated in a sliding layer portion of the sliding member used in a dry state accumulates on the sliding surface and causes seizure. The present invention has been made in view of the above situation, and accordingly an object thereof is to

provide a sliding member which can slide for a longer period of time even in a dry state.

SUMMARY OF THE INVENTION

[0007] According to the present invention, the following sliding members are provided.

[0008] (1) A sliding member provided with a sliding layer containing 1 to 20 percent by volume of bismuth powder and/or bismuth alloy powder, 20 to 60 percent by volume of metal powder, and 1 to 20 percent by volume of a solid lubricant, the sum thereof being not more than 70 percent by volume, and the balance being a thermosetting resin.

[0009] (2) The sliding member according to aspect (1), wherein the above described metal powder consists of at least one kind of copper-based alloy and aluminum-based alloy.

[0010] (3) The sliding member according to aspect (1) or (2), wherein the above described solid lubricant is formed of at least one kind of polytetrafluoro-ethylene, graphite, and molybdenum disulfide.

[0011] (4) The sliding member according to aspect (1), (2) or (3), wherein the above described thermosetting resin consists of at least one kind of phenolic resin, polyimide resin, polyamide-imide resin, and epoxy resin.

[0012] (5) The sliding member according to aspect (1), (2), (3) or (4), wherein the above described sliding member is used for a swash plate of a swash plate type piston pump.

[0013] To achieve the above object, in the invention described in aspect (1), the sliding member is provided with a sliding layer containing 1 to 20 percent by

volume of bismuth powder and/or bismuth alloy powder, 20 to 60 percent by volume of metal powder, and 1 to 20 percent by volume of solid lubricant, the sum thereof being not more than 70 percent by volume, and the balance being a thermosetting resin. According to this configuration, since a large quantity of metal powder and bismuth powder and/or bismuth alloy powder are present in mixed form in the thermosetting resin in the sliding layer, the thermal conductivity in the sliding layer is increased, so that heat does not accumulate in the sliding layer portion, by which seizure can be prevented.

[0014] In particular, bismuth and bismuth alloy (silver, tin, zinc, indium, etc. are added to bismuth; having increased wear resistance because of being harder than pure bismuth) have an advantage of improved anti-seizure property like the properties of lead. If the ratio of bismuth powder and/or bismuth alloy powder to the total quantity of sliding layer composition is lower than 1 percent by volume, sufficient abrasion properties cannot be anticipated, and if it exceeds 20 percent by volume, the wear resistance decreases gradually. The bismuth alloy is formed by adding silver, tin, zinc, indium, etc. to bismuth, and the content of added elements is in the range of 0.5 to 30 percent by mass, preferably 5 to 15 percent by mass, with respect to 100 percent by mass of bismuth. Also, the particle diameter of bismuth powder or bismuth alloy powder is preferably 1 to 50 μm. If it is smaller than 1 μm, sufficient abrasion properties cannot be anticipated, and if it exceeds 50 μm, the specific surface area decreases, so that the anti-seizure property decreases.

[0015] The metal powder consists of at least one kind of copper-based alloy and aluminum-based alloy (the invention described in aspect (2)). As the copper-based alloy, copper-tin based alloy, copper-zinc based alloy, copper-aluminum based

alloy, etc. can be thought. As the aluminum-based alloy, aluminum-tin based alloy, aluminum-silicon based alloy, etc. can be thought. These alloy powders contribute to the increase in thermal conductivity because they give off heat on the sliding surface. Also, since oil film is formed easily on the sliding surface when the sliding member is used under a lubricated condition, the alloy powders can improve the anti-seizure property from this viewpoint as well. If the ratio of metal powder to the total quantity of sliding layer composition is lower than 20 percent by volume, an effect of sufficiently increasing thermal conductivity cannot be anticipated, and if it exceeds 60 percent by volume, a binder effect of thermosetting resin is weakened, so that the strength of sliding layer decreases, by which the wear resistance is decreased. The particle diameter of metal powder is preferably 10 to 150 μm. If it is smaller than 10 μm, the metal powder agglomerates each other when being molded, and if it exceeds 150 μm, the moldability is decreased.

[0016] Also, since the sliding layer contains 1 to 20 percent by volume of solid lubricant, the coefficient of friction can be decreased, and hence the anti-seizure property can be enhanced. In this case, if the content of solid lubricant is less than 1% by volume, the effect of improving lubricity due to solid lubricant can hardly be achieved, and if it exceeds 20% by volume, a binder effect of thermosetting resin is weakened, so that the strength of sliding layer decreases, by which the wear resistance is decreased. As the solid lubricant, at least one kind of polytetrafluoroethylene (hereinafter abbreviated to "PTFE"), graphite (hereinafter abbreviated to "Gr"), and molybdenum disulfide (hereinafter abbreviated to "MoS_2") is preferably used (the invention described in aspect (3)). In this case, the

particle diameter of solid lubricant is preferably 0.1 to 50 μm. If it exceeds 50 μm, the sliding properties decrease.

[0017] In the invention described in aspect (4), the thermosetting resin consists of at least one kind of phenolic resin, polyimide resin, polyamide-imide resin, and epoxy resin. The ratio of thermosetting resin to the total quantity of sliding layer composition is the balance of the sum of bismuth powder and/or bismuth alloy powder, metal powder, and solid lubricant, and the sum other than thermosetting resin is not more than 70 percent by volume. If the sum other than thermosetting resin exceeds 70 percent by volume, a binder effect of thermosetting resin is weakened, so that the strength of sliding layer decreases, by which the wear resistance is decreased.

[0018] In the invention described in aspect (5), the sliding member is used for a swash plate of a swash plate type piston pump. By this configuration, even if the sliding member is used in a dry state, the mating member can slide for a longer period of time, and also a sudden rise in temperature of the sliding surface can be prevented. Therefore, the swash plate type piston pump can be used under severe conditions such as non lubricant, high speed, and high load.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is a plan view showing an outline of a sliding member in accordance with an embodiment of the present invention;

[0020] FIG. 2 is a sectional view taken along the line A-A of Fig. 1;

[0021] FIG. 3 is a sectional view taken along the line A-A of Fig. 1, which is similar to Fig. 2; and

[0022] FIG. 4 is a longitudinal sectional view showing an outline of construction of a swash plate type compressor.

[0023] In the above figures, reference numerals denote the following elements.

1: Sliding member

2: Base material

3: Sliding layer

4: Concave portion

5: Through hole

6: Overlay layer

20: Swash plate type compressor

22: Cylinder

29: Swash plate

30: Piston

PREFERRED EMBODIMENTS OF THE INVENTION

[0024] An embodiment of the present invention will now be described with reference to Figs. 1 to 3. Fig. 1 is a plan view showing an outline of a case where a sliding member 1 in accordance with this embodiment is applied to a swash plate of a swash plate type piston pump, and Figs. 2 and 3 are sectional views taken along the line A-A of Fig. 1.

[0025] In Fig. 1, the sliding member 1 is made up of a plate-shaped base material 2 formed of any of steel, stainless steel, copper-based alloy, aluminum-based alloy, and magnesium-based alloy and sliding layers 3 provided in both surfaces of the base material 2. In the case shown in Fig. 1, the sliding layer 3 is provided only in a portion that slides on the mating member. For this purpose, band-shaped concave portions 4 are formed slightly inside the outer periphery in both surfaces of the base material 2, and in each of the concave portions 4 is formed the sliding layer 3

in which a sliding layer composition is embedded by compression molding or injection molding. A plurality of (four in Fig. 1) through holes 5 are formed at appropriate locations of the concave portions 4, and in these through holes 5 as well, the sliding layer composition is embedded. Therefore, the sliding layers 3 formed in both surfaces of the base material 2 are connected to each other by the sliding layer composition embedded in the through holes 5. Therefore, the connection by means of the through holes 5 produces an anchoring effect, and this anchoring effect makes the sliding layer 3 less liable to be separated from the base material 2. The number of through holes 5 can be determined appropriately.

[0026] The sliding layer 3 contains 1 to 20 vol% of bismuth powder and/or bismuth alloy powder, 20 to 60 vol% of metal powder, and 1 to 20 vol% of a solid lubricant, the sum thereof being not more than 70 vol%, and the balance being a thermosetting resin. The bismuth alloy powder is formed by adding silver, tin, zinc, indium, etc. to bismuth, and the content of added elements is in the range of 0.5 to 30 mass%, preferably 5 to 15 mass%, with respect to 100 mass% of bismuth. The metal powder is selected from any one kind of copper-tin based alloy, copper-zinc based alloy, copper-aluminum based alloy, aluminum-tin based alloy, and aluminum-silicon based alloy. The solid lubricant is selected from at least on kind of PTFE, Gr, and MoS_2. The bismuth powder and/or bismuth alloy powder, metal powder, and solid lubricant are mixed with the thermosetting resin so that the sum of the contents is not more than 70 vol%. The thermosetting resin, being the balance, is selected from at least one kind of phenolic resin, polyimide resin, polyamide-imide resin, and epoxy resin.

[0027] As described above, the thermosetting resin with which the bismuth powder and/or bismuth alloy powder, metal powder, and solid lubricant are mixed is formed in the concave portions 4 in both surfaces of the base material 2 by either compression molding or injection molding, so that the sliding layer 3 can be formed so as to have a sufficient thickness. Therefore, a phenomenon that the sliding layer is worn and hence the base material is exposed can be prevented for a long period of time as compared with the sliding member in which the base material is coated with a thermosetting resin. The molding conditions in the case where phenol resin is molded by the above-described compression molding or injection molding are preferably as given in Table 1.

Table 1

Molding method	Molding condition	Proper range
Compression molding, Transfer molding	Molding temperature (°C) Molding pressure (MPa) Molding time (sec)	150 15~19 200~300
Injection molding	Cylinder temperature (front) (°C) Cylinder temperature (rear) (°C) Rotational speed of screw (rpm) Injection pressure (MPa) Molding temperature (°C) Molding time (sec)	100~110 80~90 50~60 100~150 170~180 60~120

[0028] The sectional view of Fig. 2 shows the sliding member in which the sliding layer composition is molded in the concave portions 4 and the through holes 5 in the base material 2. However, as shown in the sectional view of Fig. 3, the whole of both surfaces of the sliding member 1 shown in Fig. 2 may be coated with a polyamide-imide based overlay layer 6. When the sliding member 1 is coated with the overlay layer 6, the liability to cracking of thermosetting resin can be improved and thus the sliding properties can be enhanced.

[0029] Next, as an example of the case where the above-described sliding member 1 is used, a swash plate type compressor 20 is explained with reference to Fig. 4. Fig. 4 is a longitudinal sectional view showing an outline of construction of the swash plate type compressor 20.

[0030] The swash plate type compressor 20 compresses a gas in a cylinder 22 by a piston 30 reciprocating in the cylinder 22 following a swash plate 29 rotating in the swash plate type compressor 20. In Fig. 4, the contour of the swash plate type compressor 20 is formed by a cylinder block 21 constituting the outer peripheral portion, a front cylinder head 23 constituting the front side (left-hand side in Fig. 4), and a rear cylinder head 25 constituting the rear side (right-hand side in Fig. 4). Between the cylinder block 21 and the front cylinder head 23 is held a valve plate 24, and between the cylinder block 21 and the rear cylinder head 25 is held a valve plate 26. A part of the space surrounded by the valve plates 24 and 26 and the cylinder block 21 forms the cylinder 22. The cylinder 22 is formed into a cylindrical shape, and a plurality of cylinders 22 are arranged at equal angular intervals around a rotating shaft 27, described later. In the cylinder 22, the piston 30 reciprocating in the cylinder 22 is inserted. The piston 30 is formed into a cylindrical shape like the cylinder 22, and in the cylinder 22, a swash plate inserting portion 31 in which the swash plate 29, described later, is inserted is formed. On the side wall of the swash plate inserting portion 31, a shoe attachment portion 32 is formed to rotatably support a shoe 33 sliding in contact with the swash plate 29.

[0031] In the center of the swash plate type compressor 20, the rotating shaft 27 rotated by a driving source (not shown) is pivotally supported by bearings 28. In

the substantially central portion of the rotating shaft 27, the swash plate 29, which is an element to which the present invention is applied, is installed with mounting pins (not shown). The swash plate 29 is made up of a boss portion 29b located in the center of the swash plate 29 and a sliding portion 29a with which the shoes 33 are in slidingly contact. The boss portion 29b is formed into a substantially cylindrical shape. The sliding portion 29a is formed into a shape such that a cylinder is cut slantwise, and is formed so as to tilt with respect to the center axis of the boss portion 29b. The diameter of the sliding portion 29a is larger than that of the boss portion 29b. The sliding portion 29a is formed by either of the above-described sliding members 1 shown in Figs. 2 and 3. Specifically, the sliding layers 3 are formed on both surfaces of the sliding portion 29a, and the mating members, i.e., the shoes 33 are in slidable contact with both of the surfaces.

[0032] In a state in which the swash plate 29 is assembled to the swash plate type compressor 20, the sliding portion 29a is installed so as to tilt with respect to the center axis of the rotating shaft 27, and a part of the sliding portion 29a is located in the cylinder 22. A part of the sliding portion 29a, which is located in the cylinder 22, is inserted in the swash plate inserting portion 31 in the piston 30, and the shoes 33 are in contact with both surfaces of a part of the sliding portion 29a as described above. When the rotating shaft 27 is rotated by the driving force of the driving source in this state, the swash plate 29 also rotates, and thus the piston 30 reciprocates in the cylinder 22 following the rotation of the swash plate 29. The gas introduced into the cylinder by suction valves (not shown) provided on the valve plates 24 and 26 is compressed by the piston 30. The compressed gas is

discharged from the cylinder 22 through exhaust valves (not shown) provided on the valve plates 24 and 26.

[0033] When the piston 30 reciprocates, the sliding portion 29a slides on the shoes 33. At this time, the shoes 33 turn in the shoe attachment portion 32, so that they slide always in contact with the sliding portion 29a. Since the sliding portion 29a is formed by the sliding member 1 as described above, the exposure of the base material 2 and the separation of the sliding layer 3 from the base material 2, which are caused by the wear of the sliding layer 3 of the sliding member 1, are less liable to occur even when the swash plate 29 of the swash plate type compressor 20 rotates at a high speed or when it is subjected to a high load. Also, a sudden rise in temperature of the sliding surface can be prevented, so that the swash plate type compressor 20 can be used under severe conditions such as high speed and high load.

[0034] In the above-described swash plate type compressor 20, the shoes 33 do not come into contact with the whole surface of the sliding portion 29a of the swash plate 29. As shown in Fig. 4, on the outer and inner periphery sides of the sliding portion 29a, there are portions with which the shoes 33 do not come into contact. Therefore, the sliding layer 3 need not necessarily be formed on the whole surface of the sliding portion 29a, but may be formed only in the portions with which the shoes 33 come into contact.

[0035] Next, tests for evaluating the sliding properties of the sliding member will be described with reference to Tables 2 and 3. The tests were conducted with a thrust type testing machine by using test pieces of sliding members of examples of the present invention and conventional comparative examples.

Table 2

	Test condition	Unit
Speed	2	m/s
Surface pressure	Accumulation of 3 MPa every 30 minutes	MPa
Lubricating oil	Kerosene	-
Lubricating method	Kerosene bath	-
Shaft material	JIS S55C (quenched)	-
Shaft roughness	1 or less	Ry μm

Seizure judgement time: When back surface temperature of test piece is 140°C or when frictional force reaches 500N

Table 3

	Base material	Coat thickness	Composition (Vol%)	Seizing surface pressure
Comparative example 1	JIS S45C	50 μm	PAI+40MoS2	18MPa
Comparative example 2		200 μm	PF+40Gr	12MPa
Comparative example 3		200 μm	PF+10Cu-Sn+5Gr	12MPa
Comparative example 4		200 μm	PF+30Cu-Sn+5Gr	15MPa
Comparative example 5		200 μm	PF+80Cu-Sn+5Gr	9MPa
Example 1		200 μm	PF+30Cu-Sn+10Bi+5Gr	18MPa
Example 2		200 μm	PF+50Cu-Sn+10Bi+5Gr	21MPa
Example 3		50 μm	PF+50Cu-Sn+10Bi+5Gr	24MPa

[0036] Table 3 gives test results obtained when tests in lubricating oil were conducted on test pieces of sliding members of examples and comparative

examples having different composition of sliding layer. Table 2 gives conditions for these tests.

[0037] In Table 3, test pieces of examples 1 to 3 relating to sliding members of the present invention were used as test pieces for conducting tests, and test pieces of comparative examples 1 to 5 relating to conventional sliding members were used as test pieces for comparison. On the test pieces of examples 1 to 3 and comparative examples 1 to 5, tests were conducted under the test conditions given in Table 2, in which the seizing surface pressure at the time when a surface pressure of 3 MPa was accumulated every 30 minutes was measured in lubricating oil (kerosene). The time for judgment of seizure is as given in Table 2.

[0038] In Table 3, in comparative example 1, the sliding layer 3 with a thickness of 50 μm, in which 40 vol% MoS_2 used as a solid lubricant was mixed with PAI (polyamide-imide), being a thermosetting resin, used as a base resin, was provided by coating on the surfaces of the base material 2 consisting of JIS S45C. In comparative example 2, the sliding layer 3 with a thickness of 200 μm, in which 40 vol% Gr used as a solid lubricant was mixed with PF (phenolic resin), being a thermosetting resin, used as a base resin, was provided by compression molding on the surfaces of the base material 2 consisting of JIS S45C. In comparative example 3, the sliding layer 3 with a thickness of 200 μm, in which 10 vol% Cu-Sn used as metal powder and 5 vol% Gr used as a solid lubricant were mixed with PF (phenolic resin), being a thermosetting resin, used as a base resin, was provided by compression molding on the surfaces of the base material 2 consisting of JIS S45C. In comparative example 4, the sliding layer 3 with a thickness of 200 μm, in which 30 vol% Cu-Sn used as metal powder and 5 vol% Gr used as a solid lubricant were

mixed with PF (phenolic resin), being a thermosetting resin, used as a base resin, was provided by compression molding on the surfaces of the base material 2 consisting of JIS S45C. In comparative example 5, the sliding layer 3 with a thickness of 200 μm, in which 80 vol% Cu-Sn used as metal powder and 5 vol% Gr used as a solid lubricant were mixed with PF (phenolic resin), being a thermosetting resin, used as a base resin, was provided by compression molding on the surfaces of the base material 2 consisting of JIS S45C. As the metal powder of Cu-Sn, Cu-10 mass% Sn alloy was used.

[0039] In example 1, the sliding layer 3 with a thickness of 200 μm, in which 30 vol% Cu-Sn used as metal powder, 10 vol% bismuth powder, and 5 vol% Gr used as a solid lubricant were mixed with PF (phenolic resin), being a thermosetting resin, used as a base resin, was provided by compression molding on the surfaces of the base material 2 consisting of JIS S45C. In example 2, the sliding layer 3 with a thickness of 200 μm, in which 50 vol% Cu-Sn used as metal powder, 10 vol% bismuth powder, and 5 vol% Gr used as a solid lubricant were mixed with PF (phenolic resin), being a thermosetting resin, used as a base resin, was provided by compression molding on the surfaces of the base material 2 consisting of JIS S45C. In example 3, the sliding layer 3 with a thickness of 50 μm having the same components as those in example 2 was provided by compression molding.

[0040] In comparative examples 2 to 5, the coat thickness was equal, being 200 μm, and the added amount of metal powder was changed. In examples 1 and 2, bismuth powder was further added. From the test results, it can be thought that in comparative example 2 containing no metal powder and in comparative example 3 containing 10 vol% of metal powder, because of low thermal conductivity, heat

easily persists in the sliding surface, and resultantly the test piece becomes liable to come into direct contact with the mating shaft, which leads to seizure. Also, it can be thought that in comparative example 4, in which the added amount of metal powder is 30 vol%, the thermal conductivity can be improved by the addition of metal powder, but the seizing surface pressure is low because bismuth powder and/or bismuth alloy powder for increasing the anti-seizure property is not contained. Further, it can be thought that in comparative example 5, in which the added amount of metal powder is 80 vol%, because of the increased added amount of metal powder, the resin strength decreases and cannot withstand the load, which leads to seizure. In example 1, in which 10 vol% bismuth powder is added, the seizing surface pressure is higher than that in comparative example 4, in which the same amount of metal powder is added but bismuth powder is not added. The reason for this is thought to be that bismuth on the sliding surface is caused to flow out at elevated temperatures by the addition of bismuth powder, by which seizure is prevented like the properties of lead. It can be thought that in example 2, in which the added amount of metal powder is increased from 30 vol% of example 1 to 50 vol%, the improvement in thermal conductivity further increases the seizing surface pressure. For this reason, the sliding properties cannot be improved significantly only by the addition of metal powder even if metal powder is added in an amount that is proper to improve the thermal conductivity (comparative example 4).

[0041] Comparative example 1 and example 3 had the same coat thickness of 50 μm, but example 3 exhibited the highest seizing surface pressure of 24 MPa along with the improvement in thermal conductivity due to the addition of metal powder

and the effect achieved by the addition of bismuth powder. The reason for this is thought to be that because of small coat thickness, heat on the sliding surface is easily given off to the base material.

[0042] In comparative examples 1 to 5 and examples 1 to 3 in Table 3, the sliding members in which the overlay layers are not provided on the surfaces of the sliding layers are shown. In the experiment conducted by the applicant, for the test pieces in which overlay layers are provided on the surfaces of the sliding layers of examples 1 to 3, good results could be obtained in terms of sliding properties as compared with examples 1 to 3.

[0043] As is apparent from the above description, in the invention described in aspect (1), a large quantity of metal powder and bismuth powder and/or bismuth alloy powder are mixed with a thermosetting resin in the sliding layer, so that the thermal conductivity in the sliding layer is improved, and hence heat does not accumulate in a sliding layer portion, by which seizure can be prevented.

[0044] In the invention described in aspect (2), the alloy powder gives off heat on the sliding surface, so that the thermal conductivity is improved, by which the anti-seizure property can be enhanced.

[0045] In the invention described in aspect (3), the sliding layer contains a solid lubricant, so that the coefficient of friction can be decreased, and hence the anti-seizure property can be enhanced.

[0046] In the invention described in aspect (4), the thermosetting resin consists of at least one kind of phenolic resin, polyimide resin, polyamide-imide resin, and epoxy resin. Therefore, a sliding member having heat resistance and high strength can be provided.

[0047] In the invention described in aspect (5), even if the sliding member is used in a dry state, the mating member can slide for a longer period of time, and also a sudden rise in temperature of the sliding surface can be prevented. Therefore, a swash plate type piston pump to which the sliding member in accordance with the present invention is applied can be used under severe conditions such as non lubricant, high speed, and high load.

[0048] While the present invention has been particularly shown and described with reference to the foregoing preferred and alternative embodiments, it should be understood by those skilled in the art that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention without departing from the spirit and scope of the invention as defined in the following claims. It is intended that the following claims define the scope of the invention and that the method and apparatus within the scope of these claims and their equivalents be covered thereby. This description of the invention should be understood to include all novel and non-obvious combinations of elements described herein, and claims may be presented in this or a later application to any novel and non-obvious combination of these elements. The foregoing embodiments are illustrative, and no single feature or element is essential to all possible combinations that may be claimed in this or a later application. Where the claims recite "a" or "a first" element of the equivalent thereof, such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements.